Aerodynamic Design Using Neural Networks

In the first example, the procedure was used to reconstruct the shape of a turbine airfoil given a desired pressure distribution and some relevant flow and geometry parameters. The shape of the airfoil was not known beforehand. Instead, it was evolved from a simple curved section of nearly uniform thickness. The evolved optimal airfoil closely matched the shape of the original airfoil that was used to obtain the pressure distribution. The progression of the design is illustrated in Figure 1. The airfoil shape evolution is shown on the left, while the corresponding pressure distributions and the target pressure distribution are shown on the right. The surface pressures approach the target distribution as the design progresses until the optimal airfoil shown at the bottom has a pressure distribution that matches closely the target.

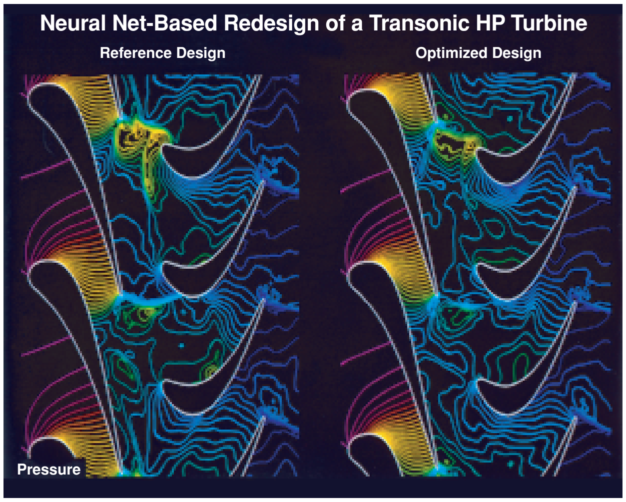

Figure 3. Stator trailing edge shock strength has been weakened substantially in the optimized design.

In the second example, the design procedure was used in a specific unsteady aerodynamic design problem, namely, the redesign of a gas generator turbine. The reference turbine was the first stage in a two-stage configuration with an aggressive design characterized by high turning angles and high specific work per stage. Although the turbine was designed to operate in the high-subsonic regime, an unsteady analysis showed very strong interaction effects due to the presence of an unsteady shock in the axial gap region between the stator and rotor rows. Since the shock can only be discerned by an unsteady aerodynamic analysis, a time-accurate Navier-Stokes solver was coupled to the neural net-based optimizer and provided simulation inputs to it. By applying the design procedure, the shocks present in the reference design (which appear as clustered contours in the region between the stator and rotor rows) were eliminated in the optimized design as illustrated in Figure 2. The optimized design was very similar to the reference design and achieved the same work output but had better unsteady aerodynamic characteristics since the flow through it was shock-free.

The third example, also related to turbomachinery, is the redesign of a transonic high pressure (HP) aircraft engine turbine. The flow in HP turbines is complicated by its inherent unsteadiness and the presence of shocks that can lead to poor aerodynamic performance, unsteady blade stresses, fatigue, vibration and reduced blade life. The design procedure was used to redesign a transonic turbine stage by optimizing the shape of the rotor and stator airfoils. The improvements achieved are illustrated in Figure 3 which shows substantial weakening of the stator trailing edge shocks in the optimized design. This led to lower unsteady pressure amplitudes on the airfoil surfaces and improved unsteady aerodynamic characteristics, without changing the work output or uncooled stage efficiency of the turbine.

The technology developed and implemented in the neural network-based design optimization procedure offers a unique capability that can be used in other aerospace applications such as external aerodynamics and multidisciplinary optimization, and has potential applications beyond aerospace design.

Technology Commercialization Status

NASA Ames currently seeks to license the Aerodynamic Design Using Neural Networks technology to U.S. companies interested in developing commercial applications. Patent pending.